Multiply-imaged supernovae with SNAP
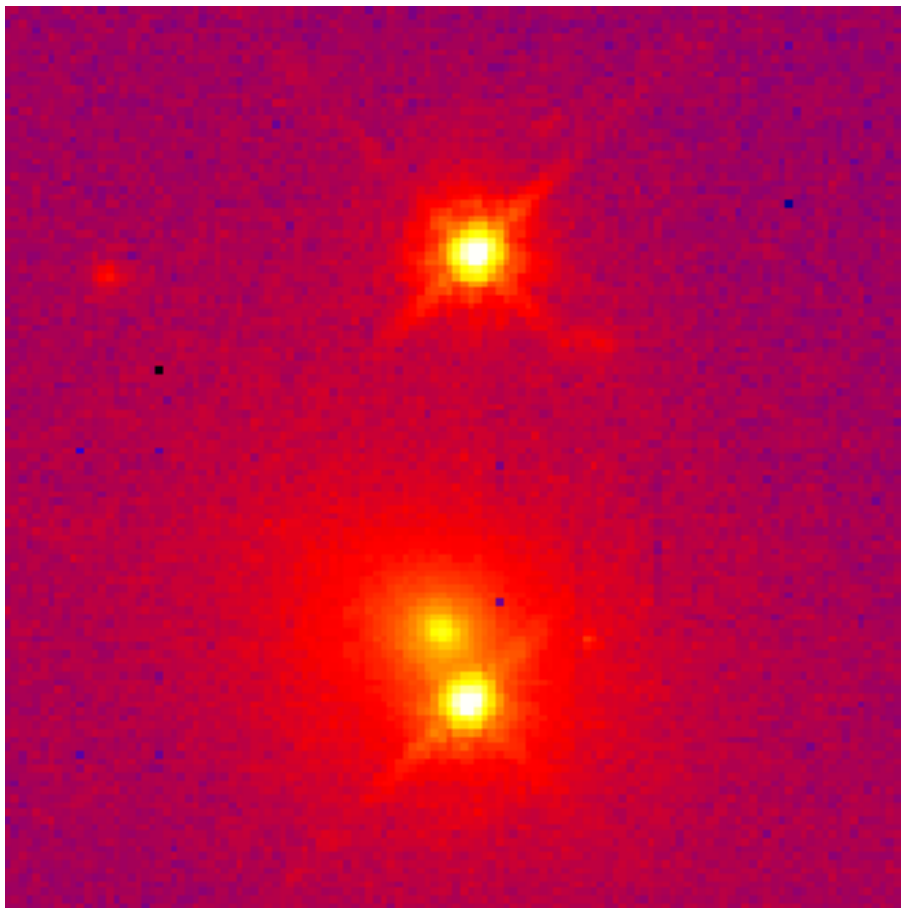

Daniel Holz
Institute for Theoretical Physics
UCSB

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What would a multiply-imaged supernova look like?

Multiple imaging signature:

- Multiple supernovae closely spaced on the sky ($\sim$ arcseconds)

- Time delay between supernovae ($\sim$ months)

- Different relative brightnesses, but identical time profiles and spectra
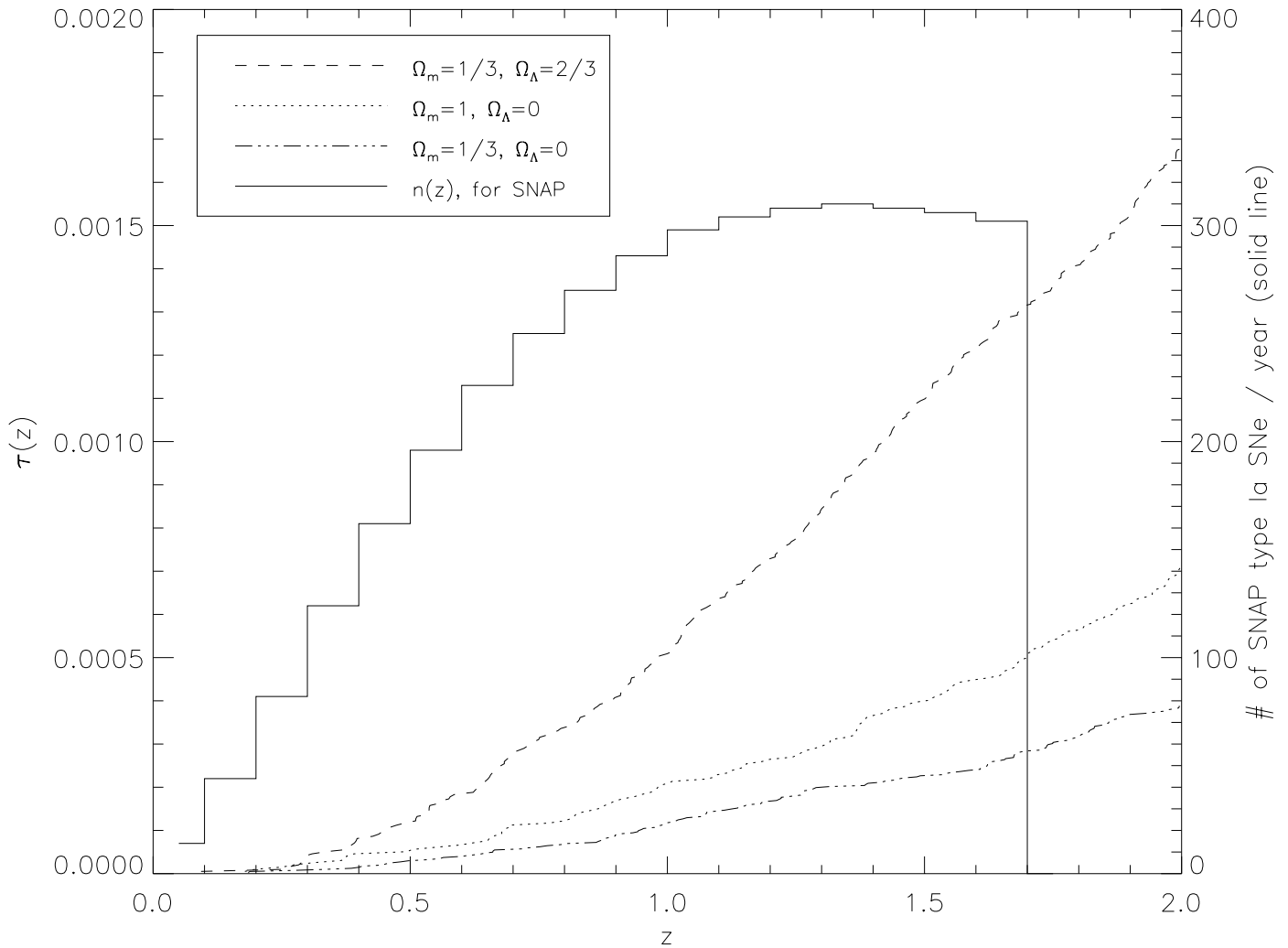

Q0957+561: A multiply-imaged quasar

Strong lensing distributions

For multiply-imaged pairs at $z = 2$, sample distributions of image separation, time delay, and image brightness (of the dimmer image).
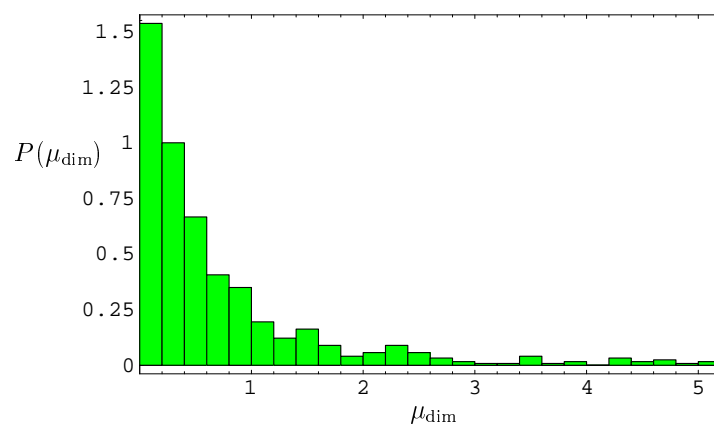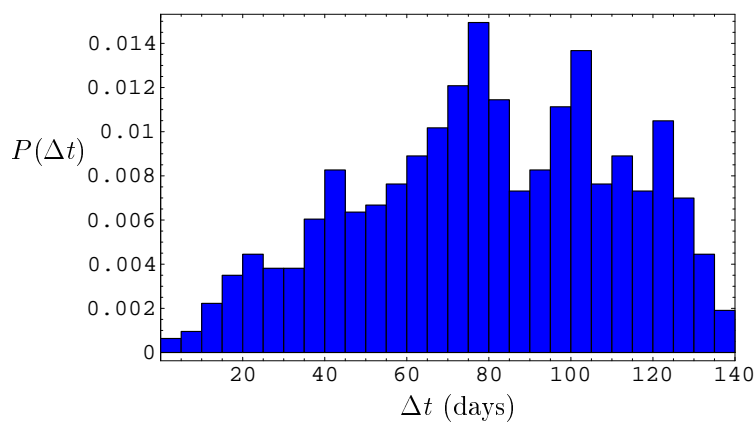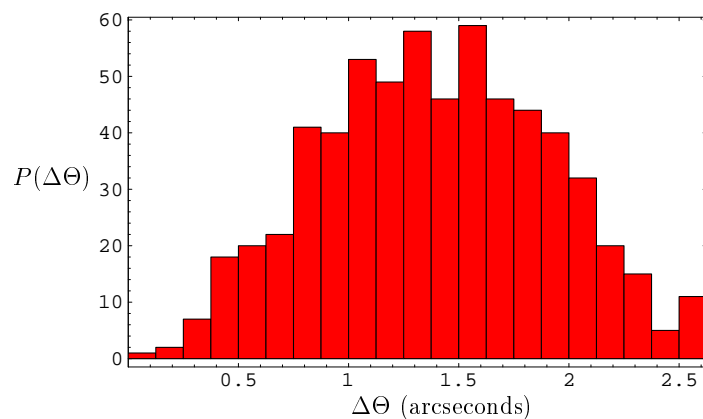
How often does multiple-imaging happen?

$\tau(z)$ is the probability for a given (point) source to be multiply-imaged (optical depth), as a function of redshift, z.

$\Rightarrow$ At $z = 2$, approximately 0.1% of sources are multiply imaged.

Note: The likelihood for strong lensing is independent of the nature of the source. Flat spectrum radio surveys (JVAS & CLASS) find:

$\sim 0.1\%$ of sources are lensed

image separations: $0.1'' \lesssim \Delta\Theta \lesssim 15''$

time delay between images: $1 \text{ week} \lesssim \Delta t \lesssim 2 \text{ years}$

Multiple-imaging and SNAP

Type Ia supernovae

- Optical depth to strong lensing

- Expected population distribution of SNe

- SNAP filters, observing strategy, etc.

- De/amplification of lensed images

- Time delays and image separations

> $\Rightarrow$ SNAP will see 2 multiply-imaged type Ia supernovae per year

Type II supernovae

- Many more than type Ia ($\sim 10^4$/year)

- Peak brightness over 2 magnitudes dimmer than type Ia

- Large intrinsic dispersion (> 1 magnitude)

> $\Rightarrow$ SNAP will see 6 multiply-imaged type II supernovae per year

Note: The rate of multiple (clustered) SNe is comparable to that of multiply imaged SNe. Distinguishing between these cases is necessary, and non-trivial.

Who cares?

Science from multiply-imaged supernovae:

- Independent measure of the Hubble constant

    - Extraordinarily accurate measurements of time delay, image separation, and relative flux
    - Break the mass-sheet degeneracy (Type Ia are standard candles)
    - Lensed SN disappears, allowing cleaner reconstruction of lens

        Co-added, deep images of (lensed) host constrains lens modeling

- Independent measure of cosmological parameters (Ω_m, Ω_Λ, fraction of macroscopic dark matter)

    - The fraction of multiply imaged sources (as a function of z) is a sensitive measure of Ω_Λ.
    - The distribution of image separations, time delays, brightnesses, morphologies, etc., are measures of Ω_m, Ω_Λ, the matter distribution within galaxies and clusters, and properties of the dark matter.

Conclusions

- It is likely that the coming decade will bring the first observations of multiply-imaged supernovae

    SNAP will certainly find such systems

- Multiply-imaged supernova systems offer independent and powerful measures of a range of important cosmological parameters